

The heavy precipitation event in Chennai, India, 1 December 2015

Science summary

Key messages

- Record rainfall in a 24-hour period led to catastrophic flooding in Chennai, India. The city was declared a disaster zone.
- The downpour occurred during the 2015 rainy season, which coincided with a strong El Niño, record warm global surface temperatures and high Indian Ocean temperatures.
- Very high levels of aerosol pollution exist over much of India, including the area around Chennai. Aerosols counteract the warming effects of greenhouse gases.
- For the extreme event attribution analysis, scientists used a multi-method approach that included climate models and observational weather data.
- No measurable effect of human-caused emissions was detected in the extreme one-day rainfall in Chennai on 1 December 2015, likely because of the masking effects of aerosol pollution.

Authors

Krishna AchutaRao, Indian Institute of Technology Delhi, New Delhi, India

Geert Jan van Oldenborgh, Royal Dutch Meteorological Institute, De Bilt, Netherlands

Friederike E.L. Otto and Karsten Haustein, Environmental Change Institute, University of Oxford, Oxford, UK

The manuscript was originally published in the special supplement to the *Bulletin of the American Meteorological Society* Vol. 97, No. 12, December 2016.¹

Context

A relentless downpour pounded Tamil Nadu's capital city of Chennai on 1 December 2015, flooding and submerging one of India's largest cities. The heaviest one-day rainfall in the region in more than a century – as much as 494 mm (19.45 inches) – left more than three million people without basic services,² collapsed roads and bridges, and halted air and train travel in and out of the city, stranding hundreds of passengers.³ “Chennai has become a small island,” said India Home Minister Rajnath Singh.⁴

The 2015 rainy season coincided with a strong El Niño, record warm global surface temperatures and high Indian Ocean temperatures. The question is which, if any, of these factors influenced the probability of extreme rainfall in Chennai

The catastrophic rains not only isolated the city, but forced tens of thousands from their homes.⁵ The military dropped food supplies to residents stranded on rooftops.⁶ For the first time in its 137-year history, the local paper went unpublished because staff could not reach the press.⁷ On 2 December, authorities declared Chennai a disaster zone.⁸

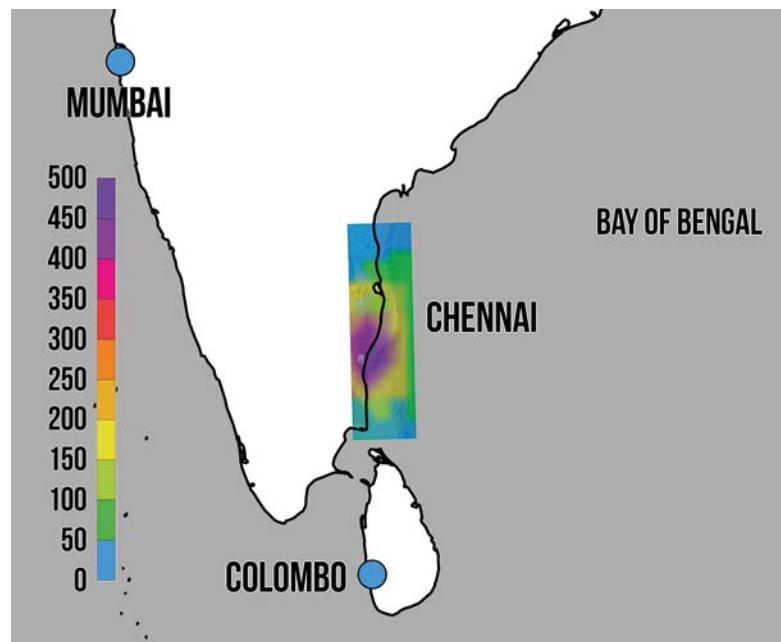
Costs to India's economy due to the flood waters in Chennai are estimated at US\$3 bn.⁹

A scientific team comprising Climate Central,¹⁰ the Royal Netherlands Meteorological Institute (KNMI),¹¹ the University of Oxford¹² and the Indian Institute of Technology Delhi (IITD)¹³ – as part of the World Weather Attribution (WWA) partnership,¹⁴ which also includes the Red Cross/Red Crescent Climate Centre¹⁵ and the University of Melbourne¹⁶ – assessed whether the downpour which affected Chennai on 1 December 2015 could in part be attributed to human emissions of greenhouse gases in the atmosphere and related climate change. This science summary, which first appeared in the *Bulletin of the American Meteorological Society*,¹⁷ outlines the team's overall methodology and conclusions. Find related materials about this event, for use by journalists and other communicators, on www.cdkn.org/climaterisk

The meteorological event

Standard daily rainfall observations in Chennai from 08.30 local time on 1 December to 08.30 on 2 December showed 24-hour sums on average of 286 mm (11.26 inches), with some stations recording as little as 77 mm (3.03 inches) and as others as much as 494 mm (19.45 inches).

Figure 1. Rain gauge observations from 08.30 on 1 December to 08.30 on 2 December 2015



The coloured box denotes the region investigated, the land area in 10°–15°N, 79.6°–81°E.

The area's main rainy season occurs from October to December during the north-east monsoon. That's when high sea surface temperature (SST) in the Bay of Bengal, coupled with weak vertical wind shear conditions ('wind shear' is the change of wind speed and direction with height), make circumstances ideal for the cyclones, tropical storms and other rain storms that landfall on the coast of south-eastern India.

The 2015 rainy season coincided with a strong El Niño, record warm global surface temperatures and high Indian Ocean temperatures.¹⁸ The question is which, if any, of these factors influenced the probability of extreme rainfall in Chennai. Overall, SSTs in the Bay of Bengal – while higher than the observed trend – were still lower than elsewhere in the Indian Ocean during the 2015 rainy season. SSTs in the northern and western Bay of Bengal have increased very little during the past 35 years compared with observed global warming trends. This is likely due to increased air pollution in the region, the 'brown cloud' that blocks sunlight. That in turn counteracts the large-scale warming due to greenhouse gases, especially in pre-monsoon maximum temperature. This is also known as the 'aerosol effect' (see box on page 4). Despite the overall cooler temperatures in the Bay of Bengal compared with elsewhere in the Indian Ocean, there was a somewhat warmer patch of water just off the coast of Chennai on 1 December.

Chennai's vulnerability and exposure

Chennai is a coastal mega-city which has encountered explosive and largely unplanned growth over the past 15 years. The city of 8.2 million has an estimated 150,000 illegal buildings.¹⁹ Land-use issues such as decreased natural areas, loss of water bodies, encroachment of river and streams and other drainage channels, and uncontrolled multiplication of built-up areas have been identified as factors that contribute to high vulnerability and exposure to floods in Chennai. On 1 December, the extreme rainfall brought nearly full reservoirs to capacity, prompting local authorities to release water into the rivers which subsequently overflowed and flooded low-lying areas.²⁰ In a report, the Parliamentary Standing Committee on Home Affairs acknowledged the lack of timely desilting, inadequate flood zone planning and large-scale settlements in low-lying areas as major contributors to the impacts that occurred in the city.²¹

Scientific analysis

To assess the potential link between the heavy rainfall in Chennai on 1 December 2015 and human-caused greenhouse gases in the atmosphere, the science team conducted independent assessments using multiple peer-reviewed approaches of extreme event attribution methodologies. These approaches involve statistical analyses of the historical precipitation record, the trend in global climate models, and the results of thousands of simulations of possible weather with a regional climate model. Applying multiple methods provides scientists with a means to assess confidence in the results.

For the observational analysis, scientists analysed two datasets of daily precipitation in the region. The public GHCN-D dataset has 50 stations with at least 40 years of data in the coastal area 10°–15°N, 79.5°–81°E for a total of 3,504 station-years. However, all but two of the series end

in 1970. The India Meteorological Department (IMD) provided 19 non-public series from the region for 1969-2013.

For the global model analysis, the team analysed the rainfall extremes in a relatively high-resolution (150-km) ensemble of model runs, 16 historical/RCP8.5 experiments using the EC-Earth 2.3 model at T159. The CMIP5 multi-model ensemble contains many models with a hard upper boundary of rainfall in the grid box corresponding to Chennai, in contrast to the observed probability distribution function, so researchers were unable to use the models. For a more regional look, the scientists analysed the rainfall extremes in the regional atmosphere-only general circulation model HadRM3P, used in the weather@home distributed computing framework.

Conclusions

The highest observed daily rainfall, 494 mm, was an extreme occurrence meteorologically, with a probability of occurrence in the current climate of one in 600 to one in 2,500 per year (95% level of confidence). This would have overwhelmed flood prevention measures in any city.

No effect of human-induced climate change was detected in the extreme one-day rainfall that caused widespread flooding in Chennai, India on 1 December 2015, neither from 1900-1970, nor from 1970-2014.

Coupled models show more extreme one-day precipitation events from 1970 to 2015, but a large ensemble of observed SST-forced models again shows no increase in the probability of extreme one-day precipitation due to human-caused emissions. (An 'SST-forced model' is a climate model without an ocean, i.e. it does not calculate the ocean temperatures itself but it is provided with the observed sea surface temperatures at every time step.) A plausible factor is the lack of increase in SSTs in the western Bay of Bengal over the last 40 years, which is not reproduced correctly by the coupled models but is realistic in the SST-forced models. We therefore discarded the results from the coupled global models as unrealistic. The other results, from observations and the SST-forced regional models, preclude an attribution of the heavy rains to human-caused factors, probably due to the two main pollutants, greenhouse gases and aerosols, having opposing effects.

There is a small but clear increase in probability of extremes in the SST-forced regional models, associated with El Niño and other non-anthropogenic SST anomalies. In the observations, the El Niño–Southern Oscillation signal is also present but not statistically significant.

No effect of human-induced climate change was detected in the extreme one-day rainfall that caused widespread flooding in Chennai on 1 December 2015

Aerosols

In climate science, the word ‘aerosol’ is generally used to mean “atmospheric particulate”, particles like dust and sea salt that occur naturally and others that come from the burning of types of fossil fuels and biomass. This is not to be confused with ozone-damaging chlorofluorocarbons (CFCs) released from spray cans. Like greenhouse gases, aerosols affect the Earth’s radiative balance, intercepting solar radiation and either reflecting it back or absorbing it high in the atmosphere. Overall, aerosols have had a cooling effect on the surface, countering global warming. However, aerosols come with a host of negative impacts, specifically on climate and weather patterns, and on human health. The World Health Organization estimates that these pollutants are one of the leading causes of worldwide mortality, contributing to as many as seven million premature deaths each year.²²

Summary of key scientific parameters

Variable	Chennai, India: Precipitation
Event definition	1-day maximum average precipitation, 08.30 local time 1 Dec 2015 to 08.30 local time 2 Dec 2015
Domain	South-eastern India, 10°–15°N, 79.5°–81°E
Observational data	GHCN-D dataset, 10°–15°N, 79.5°–81°E 19 non-public series provided by India Meteorological Department (IMD)
Models used	EC-Earth 2.3 model, at T159, about 150-km resolution (considered but not used because it showed a wrong trend in SSTs) CMIP5 (considered but not used) HadRM3P
Results	No effect of human-caused emissions was detected in the extreme one-day rainfall that caused widespread flooding in Chennai, India on 1 December 2015

Notes

- 1 van Oldenborgh, G.J., Otto, F.E.L., Haustein, K. and AchutaRao, K. (2016) ‘The heavy precipitation event of December 2015 in Chennai, India’ [in ‘Explaining extreme events of 2015 from a climate perspective’], *Bulletin of the American Meteorological Society* 97(12): S87–S91 (www.ametsoc.net/eeee/2015/17_india_precip.pdf).
- 2 Burke, J. and agencies in Chennai (2015) ‘South India floods leave three million cut off from basic services’, *The Guardian*, 3 December (www.theguardian.com/world/2015/dec/03/india-army-struggles-to-rescue-survivors-as-flood-death-toll-nears-270).
- 3 FP staff (2015) ‘Chennai submerged: 3,500 stranded at airport as worst flood in 40 years shows no signs of abating’, *Firstpost*, 3 December (www.firstpost.com/politics/marooned-and-sinking-chennai-declared-disaster-zone-met-warns-of-more-rains-2530556.html).
- 4 Burke, J. and agencies in Chennai (2015) Op. cit.
- 5 FP staff (2015) Op. cit.

- 6 Reuters (2015) 'Thousands flee Chennai floods amid fears more rain could add to death toll', *The Guardian*, 4 December (www.theguardian.com/world/2015/dec/04/thousands-flee-chennai-floods-amid-fears-more-rain-could-add-to-death-toll).
- 7 Anon. (2015) 'Chennai floods: *The Hindu* not published for first time since 1878'. London: BBC News (www.bbc.co.uk/news/world-asia-india-34981328).
- 8 Dash, N. (ed.) (2015) 'Chennai declared disaster zone, airport to remain shut till December 6'. IndiaToday.in News (<http://indiatoday.intoday.in/story/chennai-rains-crisis-may-worsen-as-more-heavy-showers-predicted/1/536708.html>).
- 9 Rana, P. (2015) 'How Chennai floods stack up against other natural disasters in 2015', *The Wall Street Journal*, 11 December (<http://blogs.wsj.com/indiarealtime/2015/12/11/how-chennai-floods-stack-up-against-other-natural-disasters-in-2015/>).
- 10 Climate Central (nd) 'Climate science'. Princeton, NJ: Climate Central (www.climatecentral.org/what-we-do/our-programs/climate-science).
- 11 KNMI (nd) 'About KNMI'. De Bilt, Netherlands: Koninklijk Nederlands Meteorologisch Instituut (www.knmi.nl/over-het-knmi/about).
- 12 University of Oxford (2016) '25 years of the Environmental Change Institute'. Oxford: University of Oxford (www.eci.ox.ac.uk/).
- 13 IITD (nd) 'Indian Institute of Technology Delhi'. Delhi: IITD (www.iitd.ac.in/).
- 14 Climate Central (nd) 'World Weather Attribution'. Princeton, NJ: Climate Central (<https://www.climatecentral.org/>).
- 15 Climate Centre (nd) 'Red Cross/Red Crescent Climate Centre'. The Hague: Red Cross/Red Crescent Climate Centre (www.climatecentre.org/).
- 16 The University of Melbourne (nd) 'Welcome to the University of Melbourne'. Melbourne: The University of Melbourne (www.unimelb.edu.au/).
- 17 van Oldenborgh et al. (2016) Op. cit.
- 18 Rukmini S. and Kumar B.A. (2016) 'Freak weather whipped up a perfect storm', *The Hindu* (www.thehindu.com/sci-tech/energy-and-environment/chennai-rains-freak-weather-whipped-up-a-perfect-storm/article7955477.ece).
- 19 Busvine, D. and Nandakumar, A. (2015) 'Forget "smart" new cities; India needs old ones to be less dumb'. UK: Reuters, 3 December (<http://uk.reuters.com/article/uk-india-flood-cities-idUKKBN0TM2VV20151203>).
- 20 Ramani, S. and Srinivasan, V. (2016) 'A wrong call that sank Chennai', *The Hindu* (www.thehindu.com/news/cities/chennai/chennai-floods-a-wrong-call-that-sank-the-city/article7967371.ece).
- 21 TNM staff (2016) 'Union gvt report of Chennai floods puts Chennai Corporation, Sewerage board in the dock', *The News Minute*, 18 August (www.thenewsminute.com/article/union-govt-report-chennai-floods-puts-chennai-corporation-sewerage-board-dock-48416).
- 22 CAICE [2014] 'Learning with CLEAR: aerosol impacts on health'. San Diego, CA: Center for Aerosol Impacts on Climate and the Environment (<http://caice.ucsd.edu/index.php/education/clear/learning-with-clear/aerosols-and-health/>).

This publication is an output from the Raising Risk Awareness project. The project is funded by the UK Department for International Development (DFID) through the Climate and Development Knowledge Network (CDKN), and by Eric and Wendy Schmidt through Climate Central, Inc. CDKN is a programme funded by DFID and the Netherlands Directorate-General for International Cooperation (DGIS) for the benefit of developing countries.

This publication has been prepared for general guidance on matters of interest only, and does not constitute professional advice. You should not act upon the information contained in this publication without obtaining specific professional advice. The views expressed and information contained in this publication are not necessarily those of, or endorsed by DFID, DGIS, Eric and Wendy Schmidt, Climate Central, Inc.; or the entities managing the delivery of CDKN; or the entities implementing this project, which can accept no responsibility or liability for such views, completeness or accuracy of the information or for any reliance placed on them. No representation or warranty (express or implied) is given as to the accuracy or completeness of the information contained in this publication, and, to the extent permitted by law, DFID, DGIS, Eric and Wendy Schmidt, Climate Central, Inc.; or the entities managing the delivery of CDKN; or the entities implementing this project do not accept or assume any liability, responsibility or duty of care for any consequences of you or anyone else acting, or refraining to act, in reliance on the information contained in this publication or for any decision based on it.

Copyright © Raising Risk Awareness 2017



Funded by



Eric and Wendy Schmidt

